Livestock Greenhouse Gas Emissions Methodology Assessment

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University Honors in International Studies
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Abstract:

Scientists have identified greenhouse gas emissions (GHGs) as a primary contributor to climate change. However, the sources emitting GHGs vary widely, as do estimates about the percent contribution of each source. Of particular concern is the role of agriculture, and more specifically that of livestock, as efforts to regulate GHG emissions from these sources may also have widespread human health and nutritional impacts. Depending on the type of methodology used to assess GHG emissions, livestock has been estimated to contribute as little as 3% to as high as 51% of total global emissions. This report seeks to determine why such a large discrepancy exists and to identify the best practices for further livestock GHG assessments.

Livestock GHG Emissions

Background Information

What Are Greenhouse Gases?

- Greenhouse gases (GHGs) are chemical compounds that allow sunlight to enter and strike the earth, but absorb the resulting infrared radiation as it heads back to space. This causes a minute increase in the Earth's temperature; as more greenhouse gases appear in the atmosphere, the overall temperature of the Earth has the potential to become warmer and warmer.
- GHGs can occur from natural or anthropogenic sources, or in some cases, are a mix of both. Water vapor, carbon dioxide, methane, and nitrous oxide have both natural and anthropogenic sources; aerosols are only anthropogenic. (1)

The major GHGs are as follows:

- Carbon Dioxide (CO_2): CO_2 comes from fossil fuels (oil, natural gas, coal), solid waste, wood and plant matter, and some chemical reactions. It can be sequestered by plants.
- Methane (CH_4): CH_4 comes from the production and transport of fossil fuels, the decay of organic waste, and results from livestock and other agricultural practices.
- Nitrous Oxide (N_2O): N_2O comes from agricultural and industrial activities and from the combustion of fossil fuels and solid waste.
- Hydrofluorocarbons (CFCs): synthetic
- Perfluorocarbons (PFCs): synthetic
- Sulfur Hexafloride (SF_6): synthetic (2)
- Indirect greenhouse gases include SO_2, NOx, CO and NMVOC (3)

How do GHGs compare to one another?

In GHG methodologies, chemical amounts are expressed in terms of the equivalent CO_2 emitted. This is because the amount and the effect of different chemical compounds have different intensities. Here's a ranking (4):
(GWP means global warming potential)

- CO_2 = 1 GWP
- Methane = 21 GWP
- Nitrous Oxide = 271 GWP
- Perfluorocarbons = 6,000-9,000 GWP
- Hydrofluorocarbons = 1,000-10,000 GWP
- Sulfur Hexafluoride = 23,900 GWP

In addition to the direct global warming potential, the length of time that some greenhouse gas emissions remain in the atmosphere is also important. Methane remains in the atmosphere for 9-15 years, and nitrous oxide has an atmospheric life of 114 years. This makes it even more imperative to reduce those emissions, as their longevity could have severe consequences for climate change.

How are GHGs tracked?

Efforts to track the type and amount of GHG emissions have been ongoing since it was increasingly recognized as a problem in the 1950s, as scientists and policy makers alike are trying to determine what percent of emissions are anthropogenic. An international guideline is submitted by the UNFCCC.

- Countries that are party to the Climate Change Convention submit national GHG inventories to the UNFCCC in accordance with Articles 4 and 12 annually. The standards are clear: "The UNFCCC Reporting Guidelines on Annex I Inventories (document FCCC/SBSTA/2004/8) for Annex I Parties and Guidelines for the preparation of national communications for non-Annex I Parties" (3)
- However, other global, regional, and local reports do not necessarily follow these guidelines.

Where does agriculture fit in?

Agriculture, which includes livestock and other meat sources, has three major GHG emissions: CO2, CH4, and N20). The CO2 emissions come primarily from decaying soil organic matter and plant litter; thus, it is limited mainly to crops. Livestock GHG emissions appear in the form of CH4 and N2O, which is produced through ruminant livestock and manures.

- According to IPCC estimates, Agriculture accounts for an estimated 5.1-6.1 GtCO2-eq/year in 2005 (10-12% of total global anthropogenic emissions)
- Agricultural CH4 and N2O emissions have increased 17% from 1990 – 2005 (about 60 MtCO2-eq/yr) (5)

And where does livestock fit in?

Livestock, often a subset in agricultural emissions data, highlights the complex nature of GHG tracking and methodologies. Current estimates about the effect of livestock range from less than 3% to as much as 51% of global emissions. This website seeks to clarify the discrepancies behind these numbers. Furthermore, it hopes to clarify what the best methodology is for calculating livestock GHG emissions.

Why is this a concern?

In addition to the obvious implications if livestock is already contributing to half of total global emissions, the rising demand for meat makes understanding the GHG emission from livestock vastly relevant and important. Factors such as an increasing population and increasing purchasing power mean that more people are eating meat. As the demand for meat soars, so too will the GHG emissions from livestock. An estimated 57% increase in global meat demand is expected by 2020, primarily in Asia and Africa. (5)

The Importance of Livestock GHG Methodologies:

Thus, livestock GHG methodologies can and should play a key role in any climate change mitigation and adaptation plans. Unfortunately, the current methodologies available are often contradictory and confusing. Therefore, this website seeks to clarify the available type of livestock GHG methodologies and the differing factors. Lastly, it will offer guidance on which methodologies are the most accurate and useful.

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An Overview of the Methodologies

In general terms, the various methodologies can be classified into two categories: those that include indirect GHG emissions from livestock, and those that only consider the direct emissions.

1. FAO: Livestock's Long Shadow
(Direct and Indirect Emissions)

Livestock's Long Shadow was released in 2006 by the FAO. It was the first global life cycle assessment (LCA) of the impact of livestock on climate change. This publication has become integral to the current conversation on livestock's GHG emissions.

As a broad overview, the study found that:

- Carbon Dioxide: Livestock Account for 9% of global anthropogenic emissions
- Methane: Livestock account for 35-40% of global anthropogenic emissions
- Nitrous Oxide: Livestock Account for 65% of global anthropogenic emissions
- Ammonia: Livestock account for 64% of global anthropogenic emissions

It estimated that these emissions form up to 18% of global anthropogenic emissions.

2. World Watch Institute: Livestock and Climate Change

This is currently the sole global life cycle assessment of livestock emissions besides the FAO publication. It was produced by a non-governmental organization, the World Watch Institute. The researchers did not produce a completely original work; instead, they analyzed Livestock's Long Shadow and addressed its perceived short comings. In particular, this includes:

- Outdated data: such as old data or specific case studies
- Overlooked emissions: such as fluorocarbon emissions; cooking emissions; production, distribution, and disposal of livestock byproducts; carbon-intensive medical treatment from animal diseases; etc...

Overall, the study found that livestock causes at least 32,564 million tons of CO_2 e per year. This is equal to over 51% of all global anthropogenic emissions.

3. Inter-American Development Bank: Agricultural Greenhouse Gas Emissions in Latin America and the Caribbean Current Situation, Future: Trends and One Policy Experiment

This is a regional study that incorporates some aspects of a life cycle assessment, but in other regards, it keeps to traditional direct livestock emission estimates. It studies direct emissions from manure management and enteric fermentation of livestock; however, the study also includes research on emissions from land use change. Land use change emissions due to livestock are especially large in the Latin America and Caribbean region, so this likely prompted the inclusion of these emissions. Overall, the study found that livestock contribute approximately 980 million tons of CO2-e every year.

4. European Union Commission: Evaluation of the Livestock Sector's Contribution to the EU Greenhouse Gas Emissions (GGELS)
(Direct and Indirect Emissions)

This study is the most recent, from late 2010. It is the first instance of a regional livestock GHG emissions life cycle assessment. It looked at many of the same factors as the FAO and World Watch Institute examined; however, it gave the total emissions estimates in not in terms of these categories, but in terms of the type of GHG emitted. Thus, it is difficult to directly compare the reports - yet the methodologies can be compared.

A total of 661 million tons of CO2-e were found to be emitted by European Union livestock. The report estimates that only 9.1 per cent of total EU emissions, or 12.8 per cent if land use and land use change emissions are included, come from livestock.

5. IPCC: 2006 Guidelines for National Greenhouse Gas Inventories, Vol. 4: Agriculture, Forestry, and Other Land Use
The IPCC provides guidelines for country reports on greenhouse gas emissions. Almost all countries report to the United Nations Framework Convention on Climate Change (UNFCCC) in an annual national report document. These guidelines, then, have provided the historic livestock GHG emissions methodology for most countries. They only examine direct emissions from livestock GHG emissions under their Agricultural Section: manure management and enteric fermentation. Some other indirect emissions from livestock fall under other auspices of the IPCC guidelines, but they are not distinguished as being related to livestock. Thus, some livestock emissions are likely incorporated under the Energy Section, Transportation Section, and Land Use Change Section. However, it is difficult to track those exact numbers, and the overall contribution of livestock to GHG emissions isn't well defined.

6. U.S. EPA Report: Inventory of U.S. Greenhouse Gas Emissions and Sinks, 1990-2009

The EPA report represents a typical individual country livestock emissions report. It assesses only the following concerning livestock specifically: enteric fermentation and livestock manure management. The EPA Report lacks many considerations made in the FAO's life cycle assessment. It disregards emissions from: nitrogen in fertilizer production, on farm fossil fuel related to feed and livestock, deforestation, desertification of pasture, cultivated soils due to tillage and liming, processing and transport.

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Livestock GHG Emissions

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Direct Emissions: Enteric Fermentation

Enteric fermentation occurs in herbivorous animals. Ruminant livestock give off the majority of methane, though non-ruminants also produce small quantities of methane. Ruminant animals have a four-compartment stomach that aids them in digesting plant matter. In the stomachs of these animals are a lot of anaerobic microbes, which thrive in the dark, oxygen-less parts of the animal's stomach. They are called methanogens, and they help decompose and ferment the food. As a result, they produce a methane (CH4) byproduct. An estimated 7-10% of the energy eaten by a ruminant is then lost to enteric fermentation. (1)

Other factors including the age, weight, and quality and quantity of feed consumed can influence the amount of total methane emitted. Generally, the more food an animal eats, more methane that is emitted.

Reports that used this emission:

Livestock's Long Shadow (FAO):

As with the manure management estimations, the FAO researchers found the IPCC emission factors to be outdated. The researchers felt that livestock production factors have changed since that time. As a result, parts of the IPCC Tier 2 data was used to find some enteric fermentation emission data for cattle and pigs. A new methane conversion equation, based on the type of manure management system, was used to calculate the enteric fermentation emissions. For other livestock, the FAO researchers used IPCC Tier 1 default emission figures, and coupled those figures with region-specific factors. The resulting estimated methane released from enteric fermentation may total **86 million tons of CH4 per year**. [This figure closely resembles a global study done by the EPA, which estimated 80 million tons per year of methane emitted annually.] (2)

Livestock and Climate Change (World Watch Institute):

(same explanation appears in Manure section)

The FAO used a 23 GWP over a 100 year time frame for methane; these authors advocate using the new 25 GWP figure or -- using the 72 over a 20 year time frame figure. This shows the immediate impact of methane better, and the latest IPCC report uses this figure. With these figures, livestock methane accounts for **7,416 million tons CO2 e**, or 11.6% of worldwide GHGs. The methane not included in the FAO figures is around 5,047 million tons CO2 e. (3)

Agricultural Greenhouse Gas Emissions in Latin America and the Caribbean (Inter-American Development Bank):

These researchers also used IPCC methodology for finding enteric fermentation and manure emissions.
They focused on all livestock, but found that mainly dairy and beef cattle are the major emitters. The researchers found that the IPCC data is insufficient for poultry and llamas, so they made their own methodology. The total estimated enteric fermentation emissions are: **4315.5 kg CO2-e**. (4)

Evaluation of the Livestock Sector's Contribution to the EU Greenhouse Gas Emissions (European Commission):

The EU also followed the IPCC 2006 methodologies. The Tier 2 methodology was used for cattle; Tier 1 methodologies were used for all other livestock. Both emissions from enteric fermentation and manure management are included in the overall estimation of livestock emissions: **323 million tons of CO2-e**. (5)

Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2009 (U.S. Environmental Protection Agency):

Beef and dairy cattle were found to be the largest emitters of CH_4 amongst U.S. livestock. Since cattle account for the most CH_4 emissions, a more detailed methodology was used for them. Emission estimates for other domesticated animals were less detailed. The methodology used was the Cattle Enteric Fermentation model (CEFM) developed by the EPA. Other data and calculations came from IPCC Tier 1 and 2 figures. The total enteric fermentation methane emitted from U.S. livestock was calculated to be around 139.8 Tg CO_2-e (6,655 Gg). (6)

2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC):

The IPCC has developed guidelines and best practices for measuring livestock enteric fermentation and manure emissions. There are two main guidelines, titled Tier 1 and Tier 2. Tier 1 uses general emissions data about livestock emissions and provides data for common livestock (dairy cattle, non-dairy cattle, buffalo, sheep, goats, camels, horses, mules and asses, swine, and poultry). It is meant to address the common livestock emissions information and data. Tier 2 is more complex; it requires country-specific information on livestock manure characteristics and management practices. It was created for use when the Tier 1 data isn't relevant to a country. (7)

Tier 1: The IPCC has collected common emission factor numbers, which countries can use to calculate their livestock's emissions. Tier 1 is should be used for livestock species that are not a major source of enteric fermentation.

Tier 2: A more complex approach that should be used for key enteric fermentation species. It requires individualized country-specific information on feed intake and methane conversion factors for livestock.

Lastly, for enteric fermentation calculations, countries have the option of using a third tier:

Tier 3: The most detailed report, which relies on countries to take data on diet composition, seasonal variations in feed, etc...

IPCC Manure Mangement Data:

TABLE 8

MANURE MANAGEMENT EMISSION FACTORS (KG PER HEAD PER YR.)

	Developed Countries			Developing Countries		
Livestock	Cool	Temp.[a]	Warm	Cool	Temp.[a]	Warm
Sheep	0.19	0.28	0.37	0.10	0.16	0.21
Goats	0.12	0.18	0.23	0.11	0.17	0..22
Camels	1.6	2.4	3.2	1.3	1..9	2.6
Horses	1.4	2.1	2.8	1.1	1..6	2.2
Mules and Asses	0.76	1.14	1.51	0.60	0.90	1.2
Poultry[b]	0.078	0.117	0.157	0.012	0.018	0.023

The range of estimates reflects cool to warm climates. Climate regions are defined in terms of annual average temperature as follows: Cool = less than 15° C; Temperate = 15° C to 25° C inclusive; and Warm = greater than 25° C. The Cool, Temperate, and Warm regions are estimated using MCFs of 1% and 2%, respectively.

[a] Temp. = Temperate climate region.

[b] Chickens, ducks, and turkeys.

All estimates are ±20%.

Sources: Emission factors developed from: feed intake values and feed digestibilities used to develop the enteric fermentation emission factors; MCF, and B_O values reported in Woodbury and Hashimoto (1993). All manure is assumed to be managed in dry systems, which is consistent with the manure management system usage reported in Woodbury and Hashimoto (1993).

Source: IPCC, 1996 (Chapter 4, Table 4.5).

IPCC Regional Enteric Fermentation Emissions:

Table 3.7

Global methane emissions from enteric fermentation in 2004

Region/country	Emissions (million tonnes CH_4 per year by source)					
	Dairy cattle	Other cattle	Buffaloes	Sheep and goats	Pigs	Total
Sub-Saharan Africa	2.30	7.47	0.00	1.82	0.02	**11.61**
Asia *	0.84	3.83	2.40	0.88	0.07	**8.02**
India	1.70	3.94	5.25	0.91	0.01	**11.82**
China	0.49	5.12	1.25	1.51	0.48	**8.85**
Central and South America	3.36	17.09	0.06	0.58	0.08	**21.17**
West Asia and North Africa	0.98	1.16	0.24	1.20	0.00	**3.58**
North America	1.02	3.85	0.00	0.06	0.11	**5.05**
Western Europe	2.19	2.31	0.01	0.98	0.20	**5.70**
Oceania and Japan	0.71	1.80	0.00	0.73	0.02	**3.26**
Eastern Europe and CIS	1.99	2.96	0.02	0.59	0.10	**5.66**
Other developed	0.11	0.62	0.00	0.18	0.00	**0.91**
Total	**15.69**	**50.16**	**9.23**	**9.44**	**1.11**	**85.63**
Livestock Production System						
Grazing	4.73	21.89	0.00	2.95	0.00	**29.58**
Mixed	10.96	27.53	9.23	6.50	0.80	**55.02**
Industrial	0.00	0.73	0.00	0.00	0.30	**1.04**

* Excludes China and India.
Source: see Annex 3.2, own calculations.

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Livestock GHG Emissions

Direct Emissions: Manure Management

Methane Emissions:

Livestock manure emit methane under anaerobic (oxygen-less) conditions. This is because the organic material within the manure begins to be decomposed by anaerobic bacteria; the results of this decomposition include methane, carbon dioxide, and stabilized organic material. Both the amount of manure produced and the amount of manure that decompose anaerobically are central to determining methane emissions. Factors that influence these two considerations are the type of manure management system and the climate.

Manure management systems can be broadly classified as either liquid or dry. Dry systems included activities such as spreading the manure daily, dry feedlots, solid storage, and unmanaged manure from pasture livestock. Liquid systems are often found in intensive livestock management systems; it occurs through manure practices using tanks or lagoons to store. These systems create ideal anaerobic conditions. The most substantial manure emissions are associated with confined animal management operations, where manure is handled in liquid-based systems. (1)

The climate can also enhance the amount of emissions given off. Wet and humid climates increase methane production in solid manure management systems. Hot climates increase methane production in liquid manure management systems. (2)

Nitrous Oxide Emissions:

Nitrogen can be found in manure as ammonia (NH3). Under aerobic conditions, the ammonia is converted to nitrate; then this nitrate is converted to N20 under anaerobic conditions. The amount of nitrous oxide emitted depends on the type of manure management system and the duration of said management. The climate may also play a factor; dry, anaerobic systems are thought to result in higher nitrous oxide emissions. Current data about the factors affecting N2O emissions are sparse; thus, the estimates may not be entirely accurate.

Reports that used this emission:

Livestock's Long Shadow (FAO):

The FAO researchers found the IPCC emission factors to be outdated (the region-specific default emission factors for methane were published over twenty years ago). The researchers felt that livestock production factors have changed since that time. As a result, parts of the IPCC Tier 2 data was used to find some manure emission data for cattle; however, data was also gathered from the FAO database, IPCC Guidelines Reference Manual. Updated conversion equations were obtained from the Houghton *et al.* (1997) report and EPA Livestock Analysis Model. For non-cattle livestock, the IPCC Tier 1 data was used. The researchers found that methane released from animal manure may total **18 million tons CH4** per year. (3)

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Livestock and Climate Change (World Watch Institute):
(same explanation appears in Ruminants and Enteric Fermentation)

The FAO used a 23 GWP over a 100 year timeframe for methane; these authors advocate using the new 25 GWP figure or -- using the 72 over a 20 year timeframe figure. This shows the immediate impact of methane better, and the latest IPCC report uses this figure. With these figures, livestock methane accounts for **7,416 million tons CO2 e**, or 11.6% of worldwide GHGs. The methane not included in the FAO figures is around 5,047 million tons CO2-e. (4)

Agricultural Greenhouse Gas Emissions in Latin America and the Caribbean (Inter-American Development Bank):

These researchers also used IPCC methodology for finding enteric fermentation and manure emissions. They focused on all livestock, but found that mainly dairy and beef cattle are the major emitters. The researchers found that the IPCC data is insufficient for poultry and llamas, so they created an additional methodology for that.

Overall, an estimated **6092.11 kg CO2-e** is emitted from manure management practices. (5)

Evaluation of the Livestock Sector's Contribution to the EU Greenhouse Gas Emissions (European Commission):

The EU also followed the IPCC 2006 methodologies. The Tier 2 methodology was used for cattle; Tier 1 methodologies were used for all other livestock. Both emissions from enteric fermentation and manure management are included in the overall estimation of livestock emissions: **323 million tons of CO2-e**. (6)

Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2009 (U.S. Environmental Protection Agency):

The EPA used the methodologies from the IPCC for calculating CH4 and N2O emissions. They found that an estimated **49.5 Tg CO2-e** were emitted from livestock manure. (7)

2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC):

The IPCC has developed guidelines and best practices for measuring livestock enteric fermentation and manure emissions. There are two main guidelines, titled Tier 1 and Tier 2. Tier 1 uses general emissions data about livestock emissions and provides data for common livestock (dairy cattle, non-dairy cattle, buffalo, sheep, goats, camels, horses, mules and asses, swine, and poultry). It is meant to address the common livestock emissions information and data. Tier 2 is more complex; it requires country-specific information on livestock manure characteristics and management practices. It was created for use when the Tier 1 data isn't relevant to a country. (8)

Methane:

The methane emissions of livestock can be found using the following formula:

$$\text{Emission Factor (kg/head/yr)} \bullet \text{Population (head)} / (10^6 \text{ kg/Gg}) = \text{Emissions Gg/yr.}$$

Tier 1 provides the emission factor estimates, so all countries are required to find is the livestock population data. It assumes manure composition, climate, and manure system usage for developed and developing countries. If a country spans a climatic zone, they can calculate the emissions based on different climate zone data.

Tier 2 calculations are more detailed; countries are required to collect information about the manure management systems and specific animal characteristics. It incorporates country-specific data on manure composition, climate, manure system, and manure production capacity.

Nitrous Oxide:

The calculations for nitrogen oxide are based on the amount of manure and how it is managed.

TABLE 1

TENTATIVE DEFAULT VALUES FOR N_2O EMISSION FACTORS FROM ANIMAL WASTE PER ANIMAL WASTE MANAGEMENT SYSTEM (KG N_2O - N/KG NITROGEN EXCRETED)

Animal Waste Management System	Emission Factor EF
Anaerobic lagoons	0.001 (<0.002)
Liquid systems	0.001 (<0.001)
Daily spread[a]	0.0 (no range)
Solid storage and drylot[a]	0.02 (0.005-0.03)
Pasture range and paddock (grazing)[b]	0.02 (0.005-0.03)
Used as fuel[c]	Not Applicable
Other systems[b]	0.005

[a] Considered to be a part of direct soil emissions from agricultural fields after spreading.

[b] Considered to be a part of direct soil emissions from animal production.

[c] Considered to be a part of emissions from energy.

Source: IPCC, 1996.

TABLE 3

TENTATIVE DEFAULT VALUES FOR NITROGEN EXCRETION PER HEAD OF ANIMAL PER REGION (KG/ANIMAL/YR)

Region	Type of Animal					
	Non-Dairy Cattle	Dairy Cattle	Poultry	Sheep	Swine	Other Animals
North America	70	100	0.6	16	20	25
Western Europe	70	100	0.6	20	20	25
Eastern Europe	50	70	0.6	16	20	25
Oceania	60	80	0.6	20	16	25
Latin America	40	70	0.6	12	16	40
Africa	40	60	0.6	12	16	40
Near East & Mediterranean	50	70	0.6	12	16	40
Asia & Far East	40	60	0.6	12	16	40

Source: IPCC, 1996.

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Comments

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Livestock GHG Emissions

Direct Emissions: Respiration

All animals breathe in oxygen and exhale CO_2. Thus, livestock arguably emit large amounts of CO_2 every year. However, this respiration is often viewed as part of a balanced cycle – the CO_2 emitted by animals is then taken in by plants, which in turn emit O_2.

Reports that used this emission:

Livestock's Long Shadow (FAO):
In accordance with the Kyoto Protocol, the FAO researchers did not include livestock respiration in their calculations. As it is part of a rapidly cycling biological system, they did not expect this to be a net source of CO_2. (1)

Livestock and Climate Change (World Watch Institute):
These authors argue that this respiration does need to be included in GHG estimates. Since the total amount livestock has been increasing rapidly while vegetation has been decreasing, they argue that this traditionally cyclical CO2 cycle is no longer in equilibrium. The researchers then argue that livestock are a human invention and should be treated in the same manner as automobiles, reasoning that "today, tens of billions more livestock are exhaling CO2 than in preindustrial days, while Earth's photosynthetic capacity has declined sharply as forest has been cleared". (2)

They based their data off of an estimate by British physicist Alan Calverd, who calculated that CO2 from livestock accounts for 21% of all anthropogenic GHG emissions. However, this estimate did not include add the new GHG respiration numbers to the total GHG emissions; thus, when the total has been increased, it makes up 13% of all GHG emissions.

This would lead to a total of **8,769 million tons CO2 e** from overlooked respiration.

2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC):
The IPCC does not consider respiration of livestock to be a source of GHG emission. Thus, any reports that are based primarily on the IPCC methodology (including the EU and Latin America and Caribbean regional estimates, as well as individual country estimates) will not have these potential emissions included. (3)

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Livestock GHG Emissions

Livestock GHG Methodology Variables: >

Indirect Emissions: Animal Feed

Nitrogen Fertilizer:

Agriculture relies on three major crop nutrients: nitrogen (N), phosphorus (P), and potassium (K). (1) The amount of these compounds found naturally in the environment were often a limiting factor in agriculture. However, the Haber-Bosch process, discovered in early 21st century, has allowed for synthetic production of nitrogen. An estimated 97% of nitrogen fertilizers used today are made using the Haber-Bosch process. (2) Since then, the use of synthetic fertilizers has risen drastically in parts of the world, most notably in the U.S., Brazil, India, and China. (3)

Many synthetic nitrogen fertilizers are produced using natural gas, or – in China's case, coal. The coal-made fertilizers emit approximately 20-25% more GHGs because of their inefficiency. An estimated 41 million tons of CO2 are emitted each year manufacturing fertilizers. (2) As a large portion of agricultural products become livestock feed, these CO2 emissions can be counted as a livestock emission.

Reports that used this emission:

Livestock's Long Shadow (FAO):
The researchers concentrated on only the top ten countries that use synthetic fertilizers on crops. They combined fertilizer use for crops with the amount of crops used to feed livestock to find the amount of nitrogen emissions related to livestock. The top ten countries, in order of total nitrogen fertilizer for livestock, are as follows: United State, China, France, Germany, Canada, United Kingdom, Brazil, Spain, Mexico, Turkey, and Argentina.

Based on these estimates, a total of around 14,000,000 tons of N fertilizer are used in producing food for livestock. When the FAO report added country estimates from the Commonwealth of Independent States and Oceania, the total jumped to 16,000,000 tons of N fertilizer. Lastly, the FAO researchers added nitrogen fertilizer emissions from crop byproducts that are fed to animals. This gave them a final total of 20,000,000 tons of N fertilizer that related to livestock (out of the total global anthropogenic emissions of 80,000,000 NH4).

The researchers then found the CO2 equivalent to this amount of nitrogen. It was calculated based on the following figures:

The energy requirements of natural gas based systems (not China) are between 33-44 GJ/ton of ammonia. The FAO also added additional energy used in packaging, transport, and application of fertilizer; they then chose a low estimate of the total energy use: 40 GJ/ton. This figure was raised to 50 GJ/ton for China, since Chinese production of nitrogen fertilizer is known to be 20-25% more inefficient. Lastly, the converted this to CO2 estimates using IPCC data:

- 26 tons of carbon = 1 TJ coal energy
- 17 tons of carbon = 1 TJ natural gas energy

Table 3.4

Co_2 emissions from the burning of fossil fuel to produce nitrogen fertilizer for feedcrops in selected countries

Country	Absolute amount of chemical N fertilizer	Energy use per tonnes fertilizer	Emission factor	Emitted CO_2
	(1 000 tonnes N fertilizer)	*(GJ/tonnes N fertilizer)*	*(tonnes C/TJ)*	*(1 000 tonnes/year)*
Argentina	126	40	17	314
Brazil	678	40	17	1 690
Mexico	263	40	17	656
Turkey	262	40	17	653
China	2 998	50	26	14 290
Spain	491	40	17	1 224
UK*	887	40	17	2 212
France*	1 317	40	17	3 284
Germany*	1 247	40	17	3 109
Canada	897	40	17	2 237
USA	4 697	40	17	11 711
Total	**14 million tonnes**			**41 million tonnes**

* Includes a considerable amount of N fertilized grassland.
Source: FAO (2002; 2003); IPCC (1997).

The total FAO estimates are: **41 million tons CO2**. (2)

Evaluation of the Livestock Sector's Contribution to the EU Greenhouse Gas Emissions (European Commission):
The EU researchers calculated nitrogen emissions based on an approach developed by the MITERRA-EUROPE project. They considered the emissions of nitrogen fertilizers during both production and application on fields, and the two major GHGs emitted (CO_2 and N_2O). The researchers examined each nutrient in the fertilizers, and calculated the emissions from energy usage in the production process and the nitrogen lost during the process.

Due to the design differences in the EU report, a clear emissions count is not given at the end of each section. However, fertilizers are included in the Industrial Section of the IPCC report; and the EU report has estimated over **11 million tons of CO2-e** are emitted in from industrial activities relating to livestock. (4)

Nitrogen Leaching and Run-Off:

Leaching refers to the flow of nitrogen below soil roots to a groundwater system. Run-off refers to the flow of nitrogen over the soil to aboveground water systems. Nitrogen leaching and run-off can occur from excess nitrogen fertilizer application and manure management treatments.

Reports that used this emission:

EU Report:

The EU report was the only report to have acknowledged the direct emissions from nitrogen leaching and run-off. These figures are embedded in Industrial Sector, which includes emissions from nitrogen fertilizers, with approximately **11 million tons of CO2-e** emitted for this sector. (4)

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Livestock GHG Emissions

Livestock GHG Methodology Variables: >

Indirect Emissions: Land Use and Land Use Change

Land-Use Change

There is a clear relationship among increasing populations, rising income, and increasing demand for meat and dairy products. (1) As this demand continues to rise, it has consequently led towards expanding ranges for livestock. In many cases, forests are converted to pastureland in order to accommodate more livestock. Evidence of this has been clearly seen in Central America and South America (2, 3).

Reports that used this emission:

Livestock's Long Shadow (FAO):
The FAO estimates that over 2.4 billion tones of CO2 are emitted every year, from land-use change related to livestock. This is by far the greatest source of GHG emissions, as deforestation releases large quantities of CO2. The researchers noted that the calculation of carbon stocks and fluxes that result from clearing forests into pastureland is extremely difficult due to the number of variables present: annual forest clearing rates, the fate of the cleared land, the carbon stored in the various ecosystems, and the way in which the stored carbon was released. If the forests are burned or are allowed to decay, there emissions are released at different times and rates. For this data, the IPCC estimate of tropic deforestation average annual flux was used. From 1980 to 1989, this rate was at 1.6 plus or minus 1.0 billion tones C as CO2.

The region most affected by land-use change is Latin America. Between 2000-2010, the pasture areas in Latin America are projected to expand into forest by an annual average of 2.4 million hectares: this is equivalent to 65% of the expected deforestation. The researchers then assumed that at least 50% of any cropland would go towards feeding the increasing livestock; however, they only used this assumption for Bolivia and Brazil (other countries could certainly have similar numbers, but there was a lack of accessible data and so it was ignored). The resulting pasture and crops for feed land converted every year from forests is equal to around 3 million hectares/year.

Based on this area of deforestation, an estimated **2.4 billion CO2-e is emitted**. (4)

Livestock and Climate Change (World Watch Institute):
The FAO accounts for GHG from land changes in livestock. The World Watch Institute counts this and counts the amount of GHG sequestration that would have happened, had the land been kept in its original form or allowed to regenerate. In that instance, the extra emissions not calculated by the FAO equal 2,672 million tons of CO2 e, an additional 4.2%. Thus, the amount of overlooked land use greater than or equal to 2,672 million tons CO2-e, making the total emissions from land-use change to be over **2.66 billion CO2-e emitted**. (5)

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Agricultural Greenhouse Gas Emissions in Latin America and the Caribbean (Inter-American Development Bank):

The researchers for the regional case study of Latin America and the Caribbean mainly examined direct GHG emissions from livestock; however, since land-use change is such a prevalent issue in these regions, it was also included in their report.

The report noted that sub-sectoral GHG emissions vary significantly by country; in Brazil, cattle contribute over 54% of the total agricultural GHG emission, while cattle may contribute less in nearby Latin American countries. Of livestock emissions, it was found that forest clearing continues to contribute significantly to GHG emissions in agriculture; almost 60% for Central America and the Caribbean. The only exceptions are agro-forest systems, which can actually replace a lot of the carbon stocks lost.

Below is a graph of the researchers' findings about the amount of land-use change that contributes towards livestock GHG emissions. It is a significant amount for almost all countries. This, then, illustrates an enormous impact of livestock that might not be considered under a traditional, direct-emissions only report on livestock GHGs. (6)

Table 5: Agricultural GHG Emissions, by Sub-Sector, 2010 and 2030

	Contribution of Sectors to Total GHG Emissions under Baseline (%)					
	2010			2030		
	Land Expansion	Cropping Activity	Livestock	Land Expansion	Cropping Activity	Livestock
Argentina	61%	6%	33%	44%	9%	47%
Brazil	40%	6%	54%	26%	7%	67%
Central America & Caribbean	59%	5%	36%	41%	7%	52%
Central South America	51%	6%	44%	27%	7%	65%
Chile	40%	7%	52%	18%	9%	73%
Colombia	26%	4%	70%	10%	4%	85%
Ecuador	50%	5%	45%	26%	6%	68%
Mexico	34%	11%	55%	16%	12%	72%
Northern South America	39%	7%	54%	18%	7%	75%
Peru	56%	8%	36%	29%	11%	60%
Uruguay	28%	6%	66%	8%	7%	85%

Evaluation of the Livestock Sector's Contribution to the EU Greenhouse Gas Emissions (European Commission):
The EU reporters found that land use change data was highly uncertain. As a result, three different scenarios were created that could encompass the current possible land use change amounts. As a result, the emissions from land use change could vary from as little as 54 million tons of CO2-e to as much as 283 million tons of CO2-e. However, the intermediary figure of **191 million tons of CO2-e** was decided on as a likely estimate.

The CO2 fluxes from carbon sequestration of the two main livestock habitats (grasslands and crop land) were based on data from the Soussana et al. (2007; 2009) report. In this report, it found that carbon sequestration in grasslands is constantly accumulating and does not have a maximum point of carbon absorption. Land converted to cropland does not accumulate carbon as effectively.

Thus, extensive livestock systems may not have as negative of an impact on GHG emissions than intensive systems, which do not often use grassland pastures. However, the benefits of extensive systems are only useful as long as the land is not overgrazed, and as long as the land is not expanded to account for higher amounts of livestock.

When determining the figures for total land use emissions, the EU researchers considered changes in the carbon stock of the above-ground biomass (plant matter) and of soil carbon stock changes. The methodology used was the IPCC Tier 1 methodology for land use changes. The data was obtained from FAO crop statistics, and the change in total cropland area in EU countries was found. In places where the total cropland increased, the researchers found specific types of crops that increased. The three scenarios were then applied, which assumed different amounts of GHG emissions based on the way the land might have been converted (from forests to cropland, from grassland to cropland, etc…). (7)

Land Use

Soil Use:

Soil often contains more carbon than above-ground plant matter in the terrestrial (land-based) carbon cycle. Soil carbon is stored through decaying plant material in anaerobic (oxygen-free) conditions. In places where the decaying material is exposed to air, the carbon is able to easily respire back into the atmosphere. The loss of soil organic carbon can be caused by land use change, particularly if the land is tilled and if less plant matter is allowed to lie fallow and decompose. (8)

Reports that used this emission:

Livestock's Long Shadow (FAO):
Livestock-related releases from cultivated soils may **total 28 million tones CO2** per year. The FAO calculated this by assuming that less than 1% of 55 billion tones of C entering the soil each year become stabilized and stored in the soil.

Large-scale intensive management systems were assumed to practice conventional tillage, which disturbs the soil and releases CO2. The science behind carbon-soil cycles is still complex, so the researchers acknowledged the possible inaccuracies of their global calculations. Using data from Sauve, et al, they assumed an annual loss rate of 100 kg CO2 per hectare per year for temperate climates. As there is an estimated 1.8 million km2 of land used for livestock feed (maize, wheat, and soybean) in this climate, around 18 million tons of CO2 would be emitted.

Tropical soils have lower average carbon content, and in tropical areas, livestock are often fed crop residues and byproducts. Thus, only a small portion of CO2 emissions would be emitted from these areas. (4)

Evaluation of the Livestock Sector's Contribution to the EU Greenhouse Gas Emissions (European Commission):

The EU researchers found the CO_2 and N_2O emissions from soil cultivation based on IPCC 2006 guidelines. They used data from Leip, et al. (2008). Only organic soils were analyzed, as inorganic soils are generally less reactive to different land management types. The total emissions from this type of land use likely fall under the EU's total emission from land use and land use change of **191 million tons of CO_2-e**. (7)

<u>**Desertification:**</u>

Overgrazing from livestock is one of the key causes of desertification. (9) The plant cover in semi-arid environments is already meager; so if livestock are allowed to graze in one area for too long, most of the plant cover will be decimated. This, in turn, causes increased soil erosion and desertification. (10) In ideally managed livestock systems, a rotating grazing system will not affect desertification – in some cases, limited grazing has been shown to produce higher plant yields, as the livestock's hooves break soil crust and livestock's manure acts as fertilizer. (11)

<u>Reports that used this emission:</u>

Livestock's Long Shadow (FAO):

Livestock occupy about 2/3rds of dry lands around the world - these are places susceptible to desertification. Studies have found the rate of desertification is estimated to be higher under pasture areas than under other land uses. Thus, calculating that soil carbon loss equal 10 tons of carbon per hectare of pasture desertification, an estimated 100 million tons of CO_2 is emitted annually. (4)

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Livestock GHG Emissions

Indirect Emissions: On-Farm Emissions

In addition to the nitrogen fertilizer used in growing crops, energy is used for other feed operations on the farm and for on-farm electricity. Other feed-related energy includes diesel used planting, harvesting, and transporting the crops. On-farm electricity often relates to livestock habitation: heating, cooling, and ventilation of shelters. These emissions are primarily CO2 emissions.

Reports that used this emission:

Livestock's Long Shadow (FAO):
The FAO estimates around **90 million tons of CO2** are emitted from on-farm livestock emissions, which suggest that the CO2 emissions from later stages in crop production are greater than those emitted during nitrogen fertilizer production.

The researchers noted a lack of scientific articles analyzing the GHG emissions of on-farm livestock-related activities. As the individual conditions present in different farming regions can drastically change, more such research is needed. They based all of their calculations on a single region that had an abundance of livestock and feed case studies, Minnesota. The researchers noted that "in the absence of similar estimates representative of other world regions it remains impossible to provide a reliable quantification of the global CO2 emissions that can be attributed to on farm fossil fuel-use by the livestock sector" (FAO). There are, then, obvious shortcomings with the following data.

The researchers used data for emissions from maize used for Minnesotan livestock in intensive systems, and applied it to global feed production and livestock populations in intensive systems. Some modifications were made to account for differing climates throughout the globe; they assumed that lower latitudes would need less energy for food production, as less energy would be needed for drying feed and there would likely be less mechanization. The resulting on-farm fossil fuel emissions were an estimated 60 million tons of CO2.

To this, more data from Minnesota was added; that of electricity (ventilation, heating, and cooling) used in livestock rearing. In the same manner as before, the Minnesota figures were applied to global scale. However, this time, the researchers assumed that the lower energy use for heating would be balanced by the lower energy efficiency. Thus, they did not modify the data depending on the latitude. These estimates resulted in **30 million tones CO2.**

Products

Wrapping it Up: Analysis and Conclusion

Sitemap

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More specific findings include:

1. More emissions are required for intensive monogastric (chickens, pigs, and other livestock without a four-stomach system) production, in both electricity needs and feed transportation emissions
2. Feed transportation resulted in the most emissions. Thus, it could be concluded that livestock systems that rely on local food would have much lower emissions.

The FAO did not have exact GHG estimates for extensive systems. However, they did conclude that since most of the feed in those systems comes from natural grasslands or crop residues, that there would be low or negligible emissions. Also, since livestock often serve dual purposes – as food and as draught power – the lack of mechanization would also lead to low emissions. While some areas of the world retain the use of animals for draught power – and this has been on the rise in West Africa, there is a trend towards increased mechanization in states like India and China. (1)

Evaluation of the Livestock Sector's Contribution to the EU Greenhouse Gas Emissions (European Commission):
The EU calculated on-farm energy usage based on an approach used in Kraenzlein (2008) research. The variables examined include: direct emissions from diesel fuel, heating gas usage, electricity usage; and indirect emissions from machinery and buildings. It also examined the emissions from pesticide usage.

In a separate section, the EU also reported on emissions from feed transport, not from livestock products. The researchers identified five different transportation categories and the associated emissions: overseas shipping, barges, lorries of 32 ton and 16 ton capacity, and railways.

These emissions would fall under the IPCC Energy Category, for which the EU found that **136 million tons CO2-e** were emitted from livestock. (2)

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Livestock GHG Emissions

Livestock GHG Methodology Variables: >

Indirect Emissions: Processing of Products

Livestock are valued for their services and for their products. In particular, meats, eggs, and dairy products are the primary reasons for livestock production. In many cases, these products are not directly available to the consumer; they must be processed and/or packaged. The transportation of livestock products to stores is another source of CO2 emissions.

Reports that used this emission:

Livestock's Long Shadow (FAO):
To calculate the processing emissions for livestock products, the researchers collected reports that had already calculated these emissions for each of the major livestock products. While many of these studies represent a single case study, they were applied to a global scale. The researchers acknowledged the high uncertainties that come with this method. They found that emissions from livestock processing may total several **tens of millions tons** of CO2 per year. Livestock processing occurs predominantly in intensive systems, not extensive systems, so the researchers only incorporate estimates from the former system. Much of the GHG emissions come from the diesel used in processing facilities.

An estimated **0.8 million or more tons of CO2** per year is emitted due to livestock product transportation. (1)

Others:
No other methodologies examined this possible emissions variable.

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Comments

Livestock GHG Emissions

Wrapping it Up: Analysis and Conclusion

Analysis:
The biggest difference between all of the reports depends on whether they included only direct emissions or also indirect emissions.

The IPCC is often the de facto site for any GHG calculations and methodologies, and they only examine the role of livestock from direct GHG emissions. As a result, many of the reports that have followed consider enteric fermentation and manure management as the sole GHG emissions from livestock.
Out of all of the reports and various methodologies, Livestock's Long Shadow has often been acknowledged as the most comprehensive and groundbreaking. The use of a life cycle assessment (LCA) in determining livestock's role in GHG emissions highlighted the shortcomings of methodologies such as the IPCC report, individual country reports, and regional reports like that on Latin America and the Caribbean. However, as it was the first of its kind, the report has also been subject to criticism that:

The Report Doesn't Go Far Enough...

The World Watch Institute challenged the methodology used by Livestock's Long Shadow and made even broader claims as to the relevance of livestock in GHG emissions - an estimated 51% of all anthropogenic emissions was caused by livestock alone. This report has been more controversial, and has caused several researchers to respond against the World Watch Institute's claims. Here are some of the arguments made against the piece:

- Part of the study examines the role of livestock respiration but ignores that of grassland absorption.
- Part of the study examines "unaccounted" land use emissions; that is, they base emissions estimates on what could have been, rather than the actual changes that have occured. This is relevant when examining the different emissions of a converted pasture land and a forest; instead of simply examining the emissions from this conversion and the current pasture land emissions, these authors also examined the carbon that could have been stored by the forest. However, this "what if" scenario lens isn't applied to anything - not to growing city populations or any other land use changes that are unrelated to livestock. If that were so, then the total world emissions would have to be higher and the percentage of livestock emissions would then be less than 51%.
- One criticism of Livestock's Long Shadow in this report regards the GWP conversion numbers for methane. The IPCC revised the GWP of methane from 23 to 25 in 2007 - thus, the 2006 FAO report used valid conversion numbers, for its time.
- As for the other arguments concerning unaccounted emissions, most of the emissions listed in the report are recognized, but lack enough scientific data to become utilized in reports at this time. (1)

A report titled "Critical Analysis of Livestock's Long Shadow: Fact Sheet" by the Cattlemen's Beef Board and National Cattlemen's Beef Association also proposed additional variables that may affect livestock GHG emissions. They argued that the emissions predicted from livestock life cycle assessments can't be compared to other global emissions, if those emissions aren't also a part of a life cycle assessment. For example, the livestock sector emissions is often compared to that of the transportation sector; however, if the transportation sector emissions only include direct emissions instead of emissions from a life cycle assessment, this is an unfair comparison. (2)

The Report Goes Too Far...

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The Report Goes Too Far...

In a piece that analyzed Livestock's Long Shadow, Dr. Mitloehner from University of California at Davis argued that the report's global scale is misleading. In Livestock's Long Shadow, 34% of the GHG emissions originate from land use change (which is primarily from deforestation). This issue is most prevalent in Latin America and Asia, not in the United States or Europe. In this instance, the author argues, the conclusions drawn by Livestock's Long Shadow may be misleading for local policymakers and consumers. (3)
Another group has opposed the FAO figures; the Cattlemen's Beef Board and National Cattlemen's Beef Association has issued a fact sheet criticizing aspects of Livestock's Long Shadow. Among the less relevant counter claims, the authors argued that some of the U.S. data used in the FAO report is flawed. Examining data from the USDA feed grain acreage data, only 690,000 metric tons nitrogen fertilzer was used to grow crops for livestock, instead of the estimated 1.725 million metric tons reported in Livestock's Long Shadow. This is approximately 1/7th of the amount. (2)

While these two reports do highlight some possible shortcomings of Livestock's Long Shadow, these counterclaims should be taken with a grain of salt. Each of the reports goes on to compare the total livestock GHG emission estimates to that predicted by the EPA - however, as shown in the methodologies section of this website, the EPA only tracks direct livestock emissions. Trying to compare direct livestock emissions methodologies with life cycle assessment methodologies is a pointless endeavor.

Conclusions:

Based on an analysis of the common livestock GHG methodologies currently used throughout the globe, it appears that the life cycle assessment of livestock has more merit than measuring only direct emissions. As reports using a LCA methodology have shown, many factors besides respiration, manure, and enteric fermentation play a large role in livestock emissions. While the first major LCA, Livestock's Long Shadow, has done an admiral job in assessing the world's livestock emissions, the variables of livestock emissions have been shown to differ in scale depending on different regions of the world. Thus, the European Union's Evaluation of the Livestock Sector's Contribution to the EU Greenhouse Gas Emissions is a step in the right direction of localizing livestock life cycle assessments. One of its findings was that only using the IPCC methodology would result in only 57% of the total livestock emissions, instead of what was covered under the life cycle assessment methodology. (4) The report was only recently released in late 2010; hopefully, its findings will spur other regions around the world to conduct similar comprehensive assessments.

What does this mean for consumers?

The many variables that can affect livestock life cycle assessment emissions can make it very confusing for consumers to know what meat products have the least impact on greenhouse gas emissions. Based on the results drawn from the methodologies studied on this website, some general guidelines can be defined:
Due to the immense carbon emissions from land change, intensive livestock systems currently emit less GHGs on a global scale than do extensive systems (this equates to about 5% and 13% of global anthropogenic emissions, respectively). (5)

According to the EU regional study, the highest emissions come from ruminant livestock; with cattle producing the highest GHG emissions/kg of meat, followed by sheep and goat meat. This is likely due to the differences in enteric fermentation between ruminants and non-ruminants. Of all livestock, poultry emits the least; because they cause very little land use change, require less feed, and do not emit large amounts of methane. (4) The exact EU estimates for major livestock is as follows:

- Cow Beef (22.2 kg CO2-eq / kg beef)
- Cow Milk (1.4 kg CO2-eq / kg raw milk)
- Pork (7.5 kg CO2-eq / kg pork)
- Sheep and Goat Meat (20.3 kg CO2-eq / kg meat)
- Sheep and Goat Milk (2.9 kg CO2-eq / kg raw milk)
- Poultry Meat (4.9 kg CO2-eq / kg poultry meat)
- Egg Production (2.9 kg CO2-eq / kg eggs) (4)

Sometimes, though, the differences in regions of the world will lead to different main considerations when eating meat. For example, in Latin America and the Caribbean, the biggest concern for any GHG emission-conscious meat eater should be about land use change. This is primarily affected by cattle; thus, other livestock would be more acceptable to eat. (6)

Lastly, while concerned meat eaters may be trying to limit their carbon footprint, the negative environmental impacts of cattle and other grazing livestock on biodiversity, pollution, and other factors should also be considered.

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